Testimony on Once Through Cooling Phase Out in California

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Thank you, Mr. Chairman and Members of the Committee. I am David Bailey, Senior Project Manager, for the Electric Power Research Institute (EPRI). EPRI is providing comments, at the request of the Natural Resources Committee (Committee), on possible legislation to phase out once-through cooling at all electric generating power stations in California. The Electric Power Research Institute (EPRI) is a non-profit, collaborative research organization conducting electricity related R&D in the public interest. EPRI has been supported voluntarily by the electric industry and other stakeholders since its founding in 1973. Our members, public and private, account for more than 90% of the kilowatt-hours sold in the U.S., and we now serve more than 1000 energy and governmental organizations in more that 40 countries.

EPRI is engaged in extensive research both nationally and in California that covers closed-cycle cooling (wet and dry) fish protection technologies and environmental issues associated with the technologies. Important considerations the Committee may want to factor into a possible once-through cooling phase out decision include:

1. California has 19 once through cooling facilities (53 individual units) currently in operation with a total electric generating capacity of 21.4 gigawatts--17 gigawatts from fossil fueled units and 4.4 gigawatts from nuclear units.
2. The nuclear units are baseloaded and in operation in excess of 90% of the time while nearly all of the fossil units operate at relatively low capacity factors, some operating only during periods of peak energy demand.
3. Wet closed-cycle cooling, while commonly used for new facilities, can be problematic to retrofit on existing facilities. Five of the fossil facilities in California are rated Difficult to retrofit, four Average to Difficult, six Average and one Easy to Average. Nuclear facilities in general are typically complicated to retrofit and thus both California nuclear facilities are rated More Difficult.
4. EPRI estimates the capital cost alone to retrofit the once through cooled facilities with wet closed-cycle cooling to be on the order of $6 billion dollars.
5. EPRI's evaluation on the ability of the 53 once through cooling units (Humboldt Bay not included) determined that approximately 20 units would be highly likely to retire,

another 20 units somewhat likely to retire, 7 units would be unlikely to retire and 6 units would be highly unlikely to retire.

6. A once through cooling phase out over a highly compressed time frame as proposed in SB 42 (which requires a phase out by 2015) is likely to result in severe electricity supply reliability impacts, especially in southern California which is already below the target reserve margin. This conclusion is supported not only by EPRI studies, but recent studies by CAISO and the Department of Energy. The summer capacity planning margin for California is 15.3%. Under current planning scenarios based on total potential of all resources the 2015 capacity margin is around 10%. EPRI model simulations project up to a combined 11,580 MW of capacity will be shutdown. This generation shutdown combined with and energy penalty and related energy capacity losses of 80 MW would put capacity margins below zero in 2015.
7. Dry cooling is increasing in use at new facilities and operates in a similar manner to an automobile radiator. The technology has never been used in the U.S. for a nuclear facility and the only know known air cooled facility operating on a nuclear unit in the world is in Siberia.
8. Dry cooling consumes about 1% to 1.5% more energy than wet cooling or approximately 5 to 8 MW more for a 500 MW facility (the total energy penalty for dry cooling ranges from 3 to 4%). The cost of dry cooling ranges from 3 to 3.5 times more in hot regions and 2 to 2.5 times more in cool regions (ex. California coastal areas) than wet cooling.
9. If all of California's fossil facilities were replaced with new combined cycle facilities of the same MW generation and employed dry cooling, a net increase of 283 MW of generation would be required to compensate for lost capacity due to the energy penalties involved.
10. While there are a number of alternative fish protection technologies available to reduce impingement and entrainment, their use for California's once-through cooled facilities is very limited due to a number of site-specific factors and the size and nature of the species entrained. Application at any of these 19 facilities would require pilot studies to address feasibility issues and/or to determine performance.
11. There are a number of other environmental consequences of cooling system retrofits the Committee may want to consider that include:
    - Greenhouse gas emissions that would result from 1) probable use of fossil fueled units to compensate for lost generation during the extended outages to retrofit nuclear units, 2) increased emissions due to probable additional fossil generation due to lost capacity if wet or dry cooling is required and 3) reduced probability that renewable generation will be used if the once through phase out timeframe is too compressed.

- While there would be some marginal increase in the fishery population reserve margin (in other words greater survival rates for impacted fish species), no measurable/noticeable increase in California's coastal fisheries is likely to result from a phase out of once through cooling.
- For some inland wetland areas such as the Cerritos Channel and Aqua Hedionda Lagoon there is likely to be a decline in productivity and local water quality as a result of the significant decrease in water circulation following deployment of once through cooling.
- A number of facilities have engaged in entrainment mitigation projects and/or installed technologies to reduce impingement and entrainment that may warrant consideration for timing of a once-through cooling phase out.

Each of these points is discussed in more detail in EPRI's comments provided in this testimony.

Introduction

EPRI is pleased to provide information to assist the Committee on issues related to the proposed phasing out of once through cooling in California's electric power generating facilities. EPRI has previously conducted studies specific to these facilities including:

- Estimates of the costs to retrofit these facilities with wet closed-cycle cooling and some considerations for dry cooling (EPRI 2007a)
- An evaluation of cooling water intake structure impingement and entrainment losses to California fisheries (EPRI 2007b)
- An evaluation of the feasibility and performance of alternative fish protection technologies and operational measures at nearly all of the power generation facilities in California employing once through cooling
- Preparation of a Comprehensive Demonstration Study for one nuclear and one fossil fuel-fired power plant and participation in preparing Proposals for Information Collection to satisfy federal 316(b) Phase II Rule requirements for most of these facilities.

EPRI also served on the State Water Resources Control Board's (SWRCB) expert review panel to provide technical input into the SWRCB 316(b) Policy.

EPRI is currently engaged in a large national study to inform EPA's Phase II (i.e. existing once through cooled electric generating stations) Rulemaking relative to closed-cycle cooling as Best Technology Available (BTA). The objectives of this research include:

1. documenting the cost of closed-cycle cooling retrofits,
2. evaluating the ability of facilities to bear the cost of retrofits,

3. quantifying the environmental and social impacts of retrofits (both positive and negative) and
4. determining the impact of cooling tower retrofit on energy production and efficiency (i.e. electric reliability risk).

While this research is national in scope it specifically includes assessments for California's facilities. While the study is still in progress, much of the analysis has been competed.

EPRI has also conducted research for the California Energy Commission on the topic of dry cooling (EPRI 2004).

The focus of EPRI's testimony is on the scientific and technical issues related to phasing out once-through cooling in California. We will not address the issue of availability of air credits to accommodate re-powering in Southern California as we have not conducted research on this issue. The issues we will address include information on potential electric system reliability relative to a once through cooling phase out, use of wet versus dry cooling, use of alternative fish protection technologies to reduce impingement and entrainment, and environmental considerations associated with a phase out. The outline for this testimony is the following:

- a brief summary of the once through cooling facilities in California
- cost to retrofit once through facilities with cooling towers
- costs and thermal efficiency comparisons between wet and dry cooling
- financial impact of retrofits
- potential electric reliability impacts of a once through cooling phase out
- potential use of alternative fish protection technologies and
- other environmental considerations

California's Once-through Cooling Facilities

There are currently seventeen fossil and two nuclear facilities that use once-through cooling in California (Table 1). The fossil facilities have a nameplate generating capacity of approximately 17 gigawatts of electric power while the nuclear facilities represent 4.4 gigawatts for a combined total of total of 21.3 gigawatts. The total design once-through cooling water flow through the fossil units is 10.4 billion gallons per day (BGD) and 4.8 BGD for the nuclear facilities for a combined flow of 14.8 BGD. While the two nuclear facilities are baseloaded, generating electricity at near design capacity in excess of 90% of the time, nearly all of the fossil facilities have relatively low capacity factors and primarily operate for only a portion of the year to meet peak energy demand. Thus, the water flow values shown are maximum numbers as flow is greatly reduced or zero when these plants are not operating. A number of the fossil facilities or specific units at these facilities have announced retirement including El Segundo, Haynes, Humboldt Bay, Encina, Potrero and South Bay.

Table 1 – California Power Plants Employing Once Through Cooling

Fossil Facilities	Utility	Source Waterbody	MW	MGD
Alamitos	AES	Cerritos Channel	1,950	1,181
Contra Costa	Mirant	San Joaquin River	690	440
El Segundo	NRG	Pacific Ocean	941	606
Encina	NRG	Agua Hedionda Lagoon	958	857
Harbor	LADWP	Pacific Ocean	75	108
Haynes	LADWP	Pacific Ocean	1,279	1,014
Humboldt Bay	PG&E	Pacific Ocean	135	142
Huntington Beach	AES	Ocean	880	514
Mandalay	Reliant	Pacific Ocean	560	254
Morro Bay	Dynegy	Morro Bay	999	668
Moss Landing	Dynegy	Moss Landing Harbor	1,899	1,224
Ormond Beach	Reliant	Pacific Ocean	1,516	685
Pittsburg	Mirant	San Joaquin RI	1,906	506
Potrero	Mirant	San Francisco Bay	362	226
Redondo Beach	AES	Pacific Ocean	1,310	891
Scattergood	LADWP	Pacific Ocean	818	495
South Bay	Dynegy	San Diego Bay	707	601
Total			16,985	10,412
Nuclear Facilities	**Utility**	**Source Waterbody**	**MW**	**MGD**
Diablo Canyon	PG&E	Pacific Ocean	2,298	2,500
SONGS	SCE	Pacific Ocean	2,150	2,335
Total			4,448	4,835

Cost of Closed-cycle Cooling Retrofits

The cost estimates provided in this section are based on the units and facilities as they are operated today. Many of these units are being considered for repowering and would likely include cooling towers (wet or dry) as part of that reconstruction. The retrofit costs are therefore not directly applicable to the repowered units but should be valuable when considering phasing out these facilities. Since wet closed-cycle cooling generally has been considered a fully acceptable means to address impingement, entrainment and thermal issues that are associated with once through cooling these costs are important for evaluating the economic feasibility of retrofitting. Also, the retrofit costs provide an estimate of the costs that ultimately are passed on to electric power consumers.

EPRI conducted a study to determine the capital and O&M cost of retrofitting these facilities with closed-cycle cooling. Under the remanded federal 316(b) rule, retrofitting these facilities with closed-cycle cooling would result in automatic compliance with 316(b) and would also be considered best available technology in terms of the thermal discharge. The cost of the estimate was based on retrofitting with wet mechanical draft closed-cycle cooling towers. Wet closed-cycle cooling would be expected to achieve a reduction in cooling water flow in excess of 90%,

The EPRI cost estimating model used for California was based on site specific cost estimates for 50 facilities throughout the US and an analysis of the degree of difficulty for retrofitting each facility. While cooling towers are a common component of new facilities, they can be highly probablematic to retrofit on existing facilities. Key factors that can make retrofits difficult are listed in Table 2. Fossil facilities are rated as either easy, average or difficult and nuclear facilities are rated as either difficult or more difficult. A report on the analysis was provided to the SWRCB (EPRI 2007) and provides details on the methodology and degree of difficulty analysis.

As a result of EPRI's national retrofit research the cost estimating model has been updated to incorporate new site-specific cost estimates as well as costs from a few actual retrofits. The model now includes site specific estimates for 77 facilities. The retrofit cost estimates in the 2007 report have been updated based on the current model and these results are provided in Table 3. Humboldt Bay was not included in this study due to its planned retirement. It is important to note that a truly accurate retrofit cost estimate requires a much more detailed site specific analysis which was beyond the scope of EPRI's study. However, the California Coastal Commission conducted an independent study to estimate retrofit capital and O&M costs, based on major cooling tower component costs. While estimates varied for some individual facilities, there was good overall agreement to within 5% between that study and the EPRI study of the total costs for the facilities evaluated in both studies. Finally, PG&E has completed a very detailed site specific analysis to evaluate the cost and feasibility of retrofitting Diablo Canyon with closed cycle cooling. PG&E has provided EPRI with this report for use in the national closed-cycle cooling study and important results are included in these comments.

The results of the EPRI study currently estimate the total capital cost to retrofit the eighteen facilities to be on the order of $5.9 to $6.3 billion (and potentially more). Importantly this estimate does not include the cost of the energy penalty that will result. The energy penalty is made up of two components. The first is a heat rate[1] penalty since the turbine exhaust pressure that will be achieved with closed-cycle cooling will be higher than that achieved with once through cooling, resulting in lower turbine efficiency. The second is that the fans and pumps in the closed-cycle cooling system require electric power to operate. Combined, these two

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[1] H Heat rate is the amount of energy put into the plant (by burning fuel) divided by the amount of electrical energy produced. In the system of units commonly used by U.S. utilities, it is expressed as "Btu per kWh". For fossil and nuclear plants the value is around 9,000 - 10,000 Btu/kWh. The gross heat rate includes the total energy generated including that used inside the plant. The net heat rate is based on the amount of energy sent out to the grid.

factors on average are likely to reduce overall facility efficiency by 2.25%. It is important to note that the heat rate penalty will be greatest during hot summer periods that are generally coincident with periods of peak power demand. The overall efficiency reduction will result in approximately a 4% reduction in the generating capacity. The result is a dual effect of lost revenue for the facility during this period in addition to a reduction in the available energy that can be supplied by the facility.

A second potentially significant cost not captured in the estimate is the lost revenue for any extended outage required to retrofit. In some cases it may be possible to complete the cooling tower construction while the facility is in operation, such that the cooling tower can be connected during a scheduled maintenance outage. However, in other cases infrastructure critical to facility operation may have to be relocated resulting in a more extended outage. Also the two nuclear facilities, in particular, would likely consider re-optimizing their condensers to minimize the heat rate penalty and reduce the amount of pumping power required for the cooling tower. This essentially requires replacing the condensers. The detailed Diablo Canyon analysis estimates that a minimum of 17 months of outage time would be required to complete the retrofit. This estimates also does not include annual O&M cost that will be in the range of tens of millions of dollars and finally, the cost estimates do not include the cost of licensing and permitting towers which can also be significant.

Table 2 – Factors that make closed-cycle cooling retrofits difficult

Factor	Description
1	The availability of a suitable on-site location for a tower
2	The separation distance between the existing turbine/condenser location and the selected location for the new cooling tower
3	Site geological conditions which may result in unusually high site preparation or system installation costs
4	Existing underground infrastructure which may present significant interferences to the installation of circulating water lines
5	The need to reinforce existing condenser and water tunnels
6	The need for plume abatement
7	The presence of on- or off-site drift deposition constraints
8	The need for noise reduction measures
9	The need to bring in alternate sources of make-up water
10	Any related modifications to balance of plant equipment, particularly the auxiliary cooling systems, that may be necessitated by the retrofit
11	Re-optimization of the cooling water system or extensive modification or reinforcement of the existing condenser and circulating water tunnels

Table 3 – Degree of difficulty and cost estimates to retrofit California facilities with wet mechanical draft closed-cycle cooling

Unit Name	EPRI Estimate	
	Ranking	MM $
Alamitos	Difficult	375
Contra Costa	Average to Difficult	85 to 140
Diablo Canyon	More Difficult	2,600
El Segundo	Difficult	125
Encina	Difficult	250
Haynes	Difficult	305
Harbor	Average	21
Huntington Beach	Difficult	150
Mandalay	Easy to Average	30 to 50
Morro Bay	Average	125
Moss Landing	Average to Difficult	225 to 370
Ormond Beach	Average	265
Pittsburg	Average	90
Potrero	Average	45
Redondo Beach	Average to Difficult	170 to 280
SONGS	More Difficult	>800
Scattergood	Average to Difficult	95 to 160
South Bay	Average	100
TOTAL		5,850 to >6,250

Wet Versus Dry Cooling

Closed-cycle cooling options for California coastal plants could be wet cooling or dry cooling. In some instances a combination of the two, called hybrid cooling, could be employed. A brief description of wet and dry systems and a discussion of the cost and performance differences between them follows.

Wet Cooling: Closed-cycle wet cooling systems have become a common component for use in steam turbine condenser cooling for the past several decades. These systems condense turbine exhaust steam in a conventional shell-and-tube surface condenser as do once-through cooling systems. However, in the closed-cycle system, the hot water leaving the condenser is pumped to a cooling tower where it is cooled by evaporating a small faction (~ 1 to 2%) of the cooling water to the atmosphere. The condensate water leaving the tower is re-circulated to the condenser to complete the cycle.

Wet cooling systems are typically designed to maintain a turbine exhaust back pressure of 2.5 inches Hga at an ambient wet bulb temperature which is exceeded no more that 0.4% of the year (approximately 35 hours per year) at full load. The systems require more operating power than required for once-through systems. In addition to power for the cooling tower fans, closed-cycle systems will consume more circulating water pumping power than do the original once-through systems. This additional power amounts typically to 1 to 1.5 % of plant output.

It should also be pointed out that depending on the facility location it may be possible to provide closed-cycle cooling make-up water from alternative sources such as waste-water treatment plant effluent. Use of such water would make performance comparable to dry cooling in terms of total water consumption and thus would minimize further any impacts to fish and aquatic life. EPRI is working with LADWP to evaluate this option at two facilities.

Dry Cooling: Dry cooling systems, while significantly less common than wet systems, are increasing in use for new facilities. Currently there are approximately fifty such systems in operation for fossil facilities of 50 MW or more in the U.S. For dry cooling at fossil plants the turbine exhaust steam is ducted directly to an air-cooled condenser where the steam is condensed with air from large fans (much like the radiator in an automobile). The condensate is returned to the steam generator to complete the cycle. No water is used or consumed in the process.

Dry cooling systems are limited by the ambient dry bulb temperature. They typically achieve a condensing temperature of approximately 40 ºF above the ambient dry bulb temperature. The selection of the design point varies but is often chosen to maintain an acceptable turbine backpressure of less than 7 inches Hga at the ambient dry bulb temperature which is exceeded no more than 0.4% of the year. The system requires operating power for the air-cooled condenser fans which amounts typically to 3 to 4% of plant output.

Dry cooling systems <u>have never been used</u> on nuclear plants in the United States and at only two nuclear plants anywhere in the world; one was a small (~100MW) plant in Germany which ceased operating over twenty years ago and one of unknown size in Siberia for which no information is available.

Cost Comparison: Cost ratios between dry and wet cooling systems can be reasonably generalized for new plants. For retrofits of existing plants, the question is much more difficult.

For new plants, both combined-cycle and steam plants, the capital cost ratio ranges from 3 to 3.5 times more for dry cooling in hot locations and from 2 to 2.5 times more in cooler places like the California coast versus wet cooling. The “annual” cost ratios are slightly lower but still in the 2.5 to 3 times range for most sites. The “annual” costs include:

1. the amortized capital cost
2. the operating power costs (pumps and fans)
3. the maintenance costs (chemicals, cleaning, parts replacement)
4. the cost of water for the wet systems (acquisition, delivery, treatment, discharge)
5. the energy penalty costs

a. increased fuel cost to compensate for lower efficiency
b. replacement energy cost (the cost for reduced summertime capacity).

For existing plant retrofits, there are two major issues.

1. Air-cooled condensers (ACC) are much bigger than wet cooling towers of comparable heat duty and occupy at least 2 to 4 times the land area of wet towers. Therefore, they are frequently much harder to locate on existing plant sites. This problem is exacerbated by the fact that they must be located close to the turbine hall unlike wet towers which can be placed 1,000 feet or more from the existing turbine/condensers.
2. By far the more important issue is that the steam turbines at existing plants are not well suited for operation with dry cooling. They are limited in operation to an exhaust pressure below 5 inches of Hga, whereas turbines selected for use with dry cooling at new plants can operate up to at least 8 in Hga. Maintaining an exhaust pressure of 5 inches Hga requires a much larger condenser than maintaining 8 inches Hga at the same heat load and ambient temperature. Therefore, the dry cooling option at existing facilities requires either a very large and expensive ACC or a new more expensive steam turbine to avoid incurring very high summertime energy and capacity penalties.

For repowering, ACC may be acceptable on a site specific basis. It will almost always be more expensive than wet cooling, but assuming adequate space; it has advantages such as no plume drift, plume visibility, or blowdown wastewater discharge.

Performance Comparisons: There are two sources of performance differences between plants equipped with wet or dry cooling. The first, noted above, is that dry cooling systems require more operating power than wet systems. The difference is approximately 1 to 1.5% additional loss of plant output (compared to wet cooling) or 5 to 8 MW for a 500 MW plant.

The second is that wet systems can maintain a lower turbine exhaust back pressure and hence a higher turbine efficiency throughout the year. The difference varies with ambient conditions and thus depends on the climate at the plant site but ranges from up to 5 inches Hga on the hottest days of summer to negligible at ambient temperatures below 30 to 40 ºF. Annual average differences for the California coast might be 2 to 3 inches Hga in the south to 1 to 2 inches Hga in the north. Heat rate penalties depend on the design characteristics of the steam turbine but range from output losses of 0.5 to 1.5% per inch Hga increase in turbine exhaust backpressure. For the case of a 3 inch Hga difference and a 1.5% loss per inch Hga this could amount to a 5% loss in output or 25MW for a 500 MW plant for dry cooling compared to wet cooling.

Applying these numbers to a combined cycle plant in California illustrates the reduced generation impact of dry cooling as an option. The normal design is one in which 2/3 of the power would be generated by the combustion turbines and 1/3 would come from the steam turbine. Assuming all of the 16,985 MW of fossil generation was replaced or re-powered with combined cycle generation, approximately 5,662 MW of generating capacity would reside with the steam turbines. Thus if dry cooling were required for all of the fossil facilities an additional 283 MW of generating capacity would be required to maintain the same level of electricity generation.

Financial Impacts of Retrofits

Regardless of legislative action, many of the aging fossil units in California are being phased out for economic reasons. Long Beach Power Plant, Contra Costa Units 1-5, Pittsburg Units 1-4, and SONGS Unit 1 each used once-through cooling and have all been retired. Humbolt Bay and South Bay have both announced retirement and plans for re-powering. El Segundo, Encina and Haynes have also announced plans for unit retirements and re-powering. Therefore, none of these plants would consider retrofit of cooling towers on the existing facilities. Depending upon the timeframe being considered by the Natural Resources Committee for action, the result would likely be compressing the time frame over which the phase out would occur.

EPRI, as part of its national study on closed-cycle cooling retrofits, conducted an evaluation of the economic impact of requiring facilities in California to retrofit. California was selected due to the availability of retrofit cost estimates for each of the once through cooling facilities. This analysis focused on eighteen of the once through cooling facilities (i.e. Humboldt Bay was not included). The analysis identified units that would likely be retired as a result of not being able to bear the cost of retrofitting and the result of those impacts on reliability (i.e. lost MW). The analysis determined that approximately 20 units totaling 6,300 MW were highly likely to shutdown. An additional 20 units were considered somewhat likely to shutdown placing a total of 11,500 MW at risk of premature retirement.

Another consideration for re-powering (as in retrofitting) is that doing so is very capital intensive. LADWP, Southern California Edison and Pacific Gas and Electric are publicly regulated entities and can pass their re-powering costs on to the rate base. AES Southland, Dynegy, Mirant, NRG and Reliant are independent power producers that sell their generation to the grid. All of the independent power producers have been hard hit by the economic downturn and with current financial markets could have difficulty raising necessary capital for retrofitting or re-powering in the near term.

Electric Reliability Impacts of a Once Through Cooling Phase Out

California Senate Bill No. 42 proposes to prohibit power generating facilities from using once-through cooling after Jan 1, 2015. The bill would also require power plants that use once-through cooling to pay a specified fee per gallon of water withdrawn from Jan 1, 2011 to December 31, 2014.

The location of once-through cooled generating facilities is the result of decisions that were driven by historical technology, economics, demographics, politics and laws. As a result, once-through cooling facilities in California are generally on the ocean and a number are centrally located within population centers that have experienced significant growth since the facilities were sited. Given the location-based significance of these facilities, the implication of their ongoing retirement has been studied. A regulation seeking to eliminate once-through cooling would change the technology requirements and operating decisions of these plants. Some old fossil units would likely shut down a few years early, others might retrofit to closed-cycle cooling and incur an energy penalty, and still others would chose to re-power with new generation technology. These decisions would affect energy production, efficiency and economic systems. California citizens could be impacted through changes in electricity prices and electricity reliability.

Reliability in Southern California is already a concern. Despite the addition of new generation and transmission projects, summer peak capacity margins are still low. Projected 2015 summer capacity margins are near seven percent, while the planning reserve margin target is 15.3% percent. Significant amounts of power are imported, resulting in heavily loaded transmission lines into the area during summer peak conditions (NERC, 2008 Summer Reliability Assessment).

Relevant Studies

Several studies completed in 2008 have examined the impacts of a closed-cycle cooling retrofit requirement for California's once-through cooling facilities:

1. EPRI analysis of the impacts of a closed-cycle cooling retrofit requirement: EPRI's national closed-cycle cooling retrofit study examined the economic impacts of a requirement for California once-through cooled units to retrofit with closed-cycle cooling or retire by 2014. The analysis employed a dynamic characterization of electrical generation in California, including factors such as unit aging and retirement, development of new generation, load growth, and energy loss due to closed cycle cooling in retrofitted units. Based on cooling tower retrofit costs, 40 of the 53 once-through cooled units would have negative profitability in a retrofit-or-retire scenario. However it should be noted that the scenario of repower or retire has not been studies with the same level of effort.

2. CAISO Old Thermal Generation Study: CAISO performed an analysis of the reliability impacts associated with proposals to re-power or retire once-through cooled generation. Two critical reliability measures were studied 1) resource adequacy and 2) local capacity requirements. Resource adequacy relates to the ability of the electric system to supply electricity and meet expected loads. Local capacity requirements refer to the amount of generation needed to meet load within local service areas, such as the Los Angeles load pocket.

3. The SWRCB Electric Grid Reliability Impacts from Regulation of Once-Through Cooling in California: The SWRCB study examined the reliability and environmental impacts associated with retirement and conversion of once-through cooled generation. The policy implementation cases studied involve a phased-out approach to retirements, with once-through cooled units retiring when their NPDES permits expire, or are limited to operate less than a specified low capacity factor.

4. Department of Energy (DOE) Electricity Reliability Impacts of a Mandatory Cooling Tower Rule: The analysis examined the loss of generating capacity due to reduced operational efficiency and early retirement of facilities that do not retrofit by 2015. DOE identified California as being at risk of having insufficient generation to maintain reliability.

Summary of Study Results

EPRI conducted an analysis of the impacts of a closed-cycle cooling retrofit requirement for several regions in the U.S., including California. The regulation evaluated in this study is quite similar to the California Senate Bill No. 42. The study indicates that a regulation requiring conversion of all facilities to closed-cycle cooling would put a total of 22,000 MW at risk of retirement in California. EPRI's analysis of a closed-cycle cooling retrofit requirement identified 20 once-through cooled units, representing 6300 MW of generating capacity, that were highly likely to shut down, and another 20 once-through cooled units, representing 5200 MW, that were somewhat likely to shut down. The summer capacity planning margin for California is 15.3%. Under current planning scenarios based on total potential of all resources the 2015 capacity margin is around 10%. EPRI model simulations project up to a combined 11,580 MW of shutdown capacity. This generation shutdown combined with an energy penalty and related energy capacity losses of 80 MW would put capacity margins below zero in 2015.

Generation capacity lost due to unit shutdowns and capacity de-ratings in certain regions can present serious low-voltage and reactive power deficit problems. The magnitude, nature and extent of the voltage issues are location-specific and static or dynamic voltage support may not be sufficient to mitigate the problem. In the Los Angeles Basin, the EPRI analysis shows Alamitos (all units), El Segundo (units 3 and 4), Huntington Beach (units 1, 2, 3A, 4A), and Redondo Beach (units 5, 6, 7 and 8) at risk for shutdown. The CAISO study identified that generation from these four plants is needed to maintain local capacity requirements and resource adequacy. When taken in context with the CAISO study, the shutdown of these plants prior to the completion of key transmission and new generation projects (many slated for completion after 2010) could present serious reliability implications and increase the probability of electric system failures. These studies jointly support the conclusion that it is important to sufficiently plan and stage the timing of transmission and new generation projects with retrofit and repowering outages to avoid potential transmission system failures and blackouts.

Additional Considerations:

Some of the additional factors that should be considered with the retrofit of closed-cycle cooling systems and the potential for repowering and replacement generation include the following:

- Location-specific feasibility and timing of new source permits, including the availability of emissions credits;
- Timing and completion of transmission projects to support increased imports; and
- Peaking and voltage regulation service for the integration of renewable generation – many once-through cooled units with low capacity factor are operated so as to provide fast-ramping generation during peak load time periods.

Potential Use of Alternative Fish Protection Technologies

EPRI has participated in assessments of alternative fish protection technologies at most of California's once through cooled generating stations. Generally in terms of cooling water intake structure impacts, entrainment (eggs and larvae entering the cooling system) by far is considered the most significant issue for fish and shellfish. Because entrainment is the more significant issue and all of the technologies that reduce entrainment also reduce or eliminate impingement, the comments provided will focus on entrainment reduction technologies. The four generally available (i.e. have been deployed at one or more electric power generating stations) entrainment reduction technologies include:

1. fine-mesh traveling screens,
2. aquatic filter barrier
3. narrow-slot wedgewire screens
4. reduction in cooling water pump flow (i.e. use of variable speed drives).

While other alternatives are in development, such as withdrawing water from filter beds and use of Filtrix candles; they are very much in an experimental phase of their development. Therefore comments are limited to the four currently available technologies.

California's once through cooling facilities present some unique challenges compared to other parts of the U.S due to the siting of these facilities. Potential use of each of these four options is briefly discussed.

Fine-mesh Traveling Screens: This technology is currently in use at a number of facilities around the U.S. It functions by replacing existing screens that are generally 3/8 inch mesh with 0.5 mm mesh screens. These screens are operated continuously to collect entrainable sized fish and shellfish and return them to the source waterbody in a manner to minimize mortality. This technology can be a relatively low cost option. The major concern with this option is performance. For some fragile species such as anchovy and sardine larvae or life stages such as eggs and very small larvae, performance is likely to be poor. For other facilities such as Alamitos and Haynes the return distance to the Pacific to a location other than the thermal plume would exceed two miles. Other facilities would also face issues with the return distances. Thus while generally feasible, site-specific pilot studies would be required to document the level of aquatic life protection that would be achieved.

Aquatic Filter Barrier (AFB): This technology is a fish exclusion device. The net is designed with a very large surface area and fine mesh such that the through net velocity is very low. Effectiveness is enhanced in the presence of an ambient current sweeping velocity to carry entrainable life stages past the AFB. This technology has only been deployed in a full scale manner at the Lovett Generating Station on the Hudson River in New York. After several years of development it was determined to be very effective in preventing impingement and significantly (in excess of 80%) reducing entrainment. The difficulty with this technology is that the large surface area necessary to create the low through screen velocity requires a very long net. Therefore its use is limited to facilities with intakes in protected rivers or estuaries with relatively deep water in close proximity to the intake structure making it infeasible for the inshore facilities. It is not considered feasible for the facilities located on the ocean since it could not sustain Pacific storm events. It is therefore not considered feasible for any of California's once through cooling facilities.

Cylindrical Wedgewire Screens: Cylindrical narrow-slot wedgewire screens work in a manner similar to the AFB in that this is an exclusion technology that works by providing a large surface area with a low through slot velocity (i.e. less than 0.5 fps). However, significantly less space is required due to the circular shape of the individual screen modules that vary in size from 2 ft to over 8 ft in diameter. The slot size assumed for California is 0.5 mm which is considered the feasible limit. The number and size of modules required is a function of water depth and cooling water flow. This technology generally provides a relatively high level of performance but may not exclude the smallest entrainable life stages for some species.

There are a number of feasibility concerns for California's facilities. One of the most significant is biofouling control. This technology is normally designed with an air burst system to control biofouling and/or debris buildup on the screens. Compressed air is released when pressure builds up due to clogging of the screens and the debris or fouling organisms are blown off and carried away by ambient currents. The difficulty is that, due to long intake tunnels at the six facilities with offshore intakes, the air compressors would need to be located offshore on some type of marine platform. There is further concern over how far offshore modules would need to be located in order to sustain the impact of the hydraulic forces generated by waves during storm events. For two facilities, Alamitos and Haynes, their inland location and navigation channels and/or harbors between the facilities and the ocean make this option highly impractical.

Because of the uncertainty regarding fouling control and performance for smaller organisms, this option would require pilot study to address feasibility and performance issues prior to full scale deployment.

Reduced Cooling Water Pump Flow: Two of California's facilities, Contra Costa and Pittsburg, currently employ use of variable frequency drive pumps. These pumps function similar to a rheostat for a light switch to allow flow control for the condenser cooling water pumps which normally are designed to be either on or off. The result is that during diel or seasonal periods of off peak demand, flow can be reduced significantly and still meet generation cooling water needs. It is generally assumed that a proportional relationship exists between flow and entrainment. For baseloaded facilities such as Diablo Canyon and SONGS there would be very little benefit due to the continuous high load at which these facilities operate. For the fossil facilities, due to their generally low capacity utilization, they already tend to reduce flow by turning off some pumps due to the cost of pump operation. It is not clear to what extent it is possible to further reduce flow without impacting power generation. The question on performance in terms of reducing entrainment is further complicated by the issue of coincidence of the periods of high densities of entrainable life stages in the source waterbody and the periods when flow can be reduced. This problem would require careful analysis since the periods of larval densities vary among species as well as between years. As a result, use of this option alone would not be expected to achieve a high level of performance.

Environmental Considerations

Since the overall goal of phasing out once through cooling facilities is to benefit California natural resources, a number of comments are provided to inform the Committee on overall environmental considerations.

Air Emission and Greenhouse Gases: In addition to reducing the environmental impacts of once through cooling, California is also on a path to reduce greenhouse gas emissions because of concerns over climate change. Depending on the timing and nature of a phase out of once through cooling there are potential implications for greenhouse gas emissions. These considerations include:

- If there is a mandate for use of dry cooling there will be the need for an additional 283 MW of additional generating capacity needed to compensate for the energy penalties associated with that option. The Committee may want to consider the impact of the incremental CO_2 emissions as a result of the probable use of fossil fuel consumed to generate this power compared to the energy replacement requirements for wet cooling.
- Requiring the two nuclear facilities to retrofit with wet or dry cooling may also result in increased fossil fuel combustion (such as the probable use of gas turbines to replace existing capacity) since nuclear facilities do not generate greenhouse gases. Additionally, due to reoptimization, these facilities are likely to be off line for an extended period. The estimate for Diablo Canyon is 17 months. The 4,448 MW generated by these baseloaded facilities will need to be made up by other sources of energy.

- The more compressed the time frame for the phase out, the less opportunity there will be to replace this generation with renewables.

Resulting Benefits to California's Fisheries: As the Committee considers the timeframe for phasing out once through cooling, it may also want to consider the expected magnitude of the benefits to fish and shellfish. A key point is that entrainment impacts are often overstated. For example, California Senate Bill 42 states that "once through cooling systems kill over 79 billion fish and other marine organisms…." This statement is somewhat misleading since the vast majority of these fish are larvae rather than adult or even juvenile fish. Fish, depending on the species, produce thousands or millions of larvae with the expectation that only a few will become reproducing adult fish. The result is that 99% of the smallest larvae do not survive to become adult fish regardless of entrainment. Studies have been conducted at a number of California's once through facilities to document entrainment losses as a percent of the overall densities of these early life stages moving past the intake. The studies have determined that entrainment losses are generally less than 1% to a few percent with the exception of a few species at a few facilities where losses were as high as 12%. The result is that eliminating once through cooling is unlikely to result in any measurable increase in populations for any of the species commonly entrained. This is not to say there is no benefit, only that it is likely to be a very small benefit.

Water Quality Impacts: There are a number of facilities including Alamitos, Encina, Haynes and South Bay for which the cooling water flow provides the benefit of improved water quality and productivity to wetlands and local waters that otherwise would become stagnant. This benefit offsets to some degree, although not quantified, the current negative impacts of once through cooling.

Currently Installed Fish Protection Technologies and Mitigation Measures: The Committee, in considering a once through cooling phase out, may also want to consider that some facilities have taken mitigation measures to address adverse entrainment environmental impacts and/or installed various forms of technology. In terms of entrainment mitigation measures, Huntington Beach (for units 3&4), Moss Landing and SONGS have all engaged in wetland restoration projects scaled to offset once through cooling entrainment losses. While the Huntington Beach and SONGS projects have not yet been completed they will move forward regardless of legislative action. While the Second Circuit 316(b) Decision precludes use of mitigation for compliance it may warrant consideration for phase out timing.

A number of once through cooling facilities have also installed fish protection technologies. The six facilities with offshore intakes (El Segundo, Huntington Beach, Ormond Beach, Redondo Beach, Scattergood and SONGS) have all installed velocity caps which have been demonstrated to reduce impingement losses by approximately

80% or more. In addition, SONGS has installed a fish collection and return system to further reduce impingement. Finally, both Contra Costa and Pittsburg have each installed variable frequency drives which provide both an impingement and entrainment benefit.

References

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